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Status of Farmland Abandonment and Its Determinants in the Transboundary Gandaki River Basin

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Abstract: Farmland abandonment is a common phenomenon worldwide, including in the Gandaki River Basin (GRB) in the central Himalayas. This study examined the status of farmland abandonment, along with its trends and determinants, based primarily on interviews with 639 households in different physiographic regions: Mountain, Hill, Tarai and Gangetic Plain (GP). Binary logistic regression was used to examine the contributions of various factors of farmland abandonment. The results indicate that nearly 48%, 15%, 4%, and 16% of total farmland (khet and bari) in the Mountain, Hill, Tarai and GP regions, respectively, has been abandoned. Such differences in the proportion of farmland abandonment among the regions are mainly due to variations in biophysical conditions, agricultural productivity, access to infrastructure facilities, off-farm employment opportunities, and the occurrence of natural hazards. The major determinants for farmland abandonment were also found to vary within the region. Distance from market centers to residence, reduction in the labor force as a result of migration, and household head age were found to be significant factors in farmland abandonment in the Mountain region. Similarly, in the Hill region, eight significant factors were identified: distance from market centers to residence, distance from residence to farmland, lack of irrigation facilities (p = 0.004), reduction in labor force (p = 0.000), household head occupation, lack of training for household head and size of bari land. Household head occupation and household head age were found to play significant roles for farmland abandonment in the Tarai region. In the GP region, distance to market centers and lack of irrigation facilities had positive relationships with farmland abandonment. It is suggested that specific policies addressing the differences in physiographic region, such as horticulture and agroforestry for the Mountain and Hill regions and crop diversification and the adaptation of drought tolerant species with improvement in irrigation systems for the GP region, need to be formulated and implemented in order to utilize the abandoned farmland and have environmental, economic, and sustainable benefits.

Keywords: farmland abandonment; driving factors; logistic regression; Gandaki River Basin

1. Introduction

Changes in land use patterns are very important because of their effects on the environment and human livelihood [1]. One example of such a change occurs in farmland, the abandonment of which is a commonly observed phenomenon in different parts of the world [2–5]. Farmland abandonment

refers to a reduction in the area of agricultural land brought about by a shift in land use accompanied by less intensive production [6]. Abandoned farmland is generally defined as land previously used for agriculture and that has not been converted into urban areas or forests [7]. In recent years, farmland abandonment has been increasing in different spatial and temporal scales across the globe [2,4,8–10]. Various factors contribute to farmland abandonment, even within the same region [4]. These drivers range from the socio-economics of landownership to political and environmental factors [11–13]. The increase in farmland abandonment is attributed by migration of people (rural to urban and abroad) for service opportunities [8,14,15]. Similarly, migration has contributed to the abandonment of rural farmland in many provinces of China [5]. Due to high rates of youth migration from rural Southern Ethiopia, farmland was abandoned in recent years [14]. Thus, migration is considered to be a significant contributor to farmland abandonment, particularly in rural villages in Nepal [3,16]. In addition to migration, decreased population, resulting from epidemic disease, was also reported to be an important factor contributing to farmland abandonment in rural villages of western and northern Europe in the 14th century [17]. In recent years, increasing farmland abandonment has created challenges related to food security in many mountainous regions in China [18]. From 2000 to 2010, abandoned farmland totaled 147 million mu (1 mu = 666.67 m^2) in the mountainous regions of China and it is expected to increase by 114 million mu to 203 million mu between 2010 and 2030 [19].

The decline in agricultural productivity and increase in off-farm occupations are also well-known causes of farmland abandonment in the mountainous regions of Nepal [20]. In India, land heterogeneity, lack of irrigation facilities, distance from residence to farming plots, soil quality and lack of resources (human and water) were reported to be important factors contributing to farmland abandonment [21,22]. Household size, age of the household head, land ownership type, off-farm income, and road accessibility were found to play key roles in farmland abandonment in the mountainous regions of Nepal [23]. The elevation, slope, and size of a farmland parcel are also important factors of farmland abandonment in the mountainous regions of China [24]. Access to transportation, soil quality, and farmland distance to residence were reported as key determining factors in farmland abandonment in Western Siberia and post-Soviet Russia [10]. Climatic conditions, farm management, socio-economic conditions, and soil quality were found to contribute to farmland abandonment in the mountainous region of Europe [2,11]. A satellite image-based study found that a total of 52.5 million hectares of farmland were abandoned in European Russia, Northern and Western Ukraine, and Belarus between 2004 and 2006 [12].

Farmland abandonment is a serious environmental problem that has significant effects on livelihood, even in developed countries such as in Japan [4] and the United States (e.g., rural western New York state) [25]. The changing farmland to wilderness pastoral and shrub have a noticeable impact on the local environment in the high mountainous region of Nepal [16]. A few case studies have been carried out in villages in the Gandaki River Basin (GRB) in Nepal [8,20,23,26]. The status and drivers of land abandonment are likely to differ among physiographic regions. The physiographic region of Nepal is divided mainly based on landform characteristics, altitude, climatic zone, and river relief [27]. Each region is unique due to diverse landforms, climatic conditions, different agricultural practices, and the socio-economic characteristics of the people. Some previous studies were focused on a specific time and area. To capture the variation in farmland abandonment processes and drivers by time and space, an understanding of different physiographic and socio-economic contexts is necessary. The transboundary GRB covers all the physiographic region of Nepal as well as Gangetic Plain of India, with different socio-economic conditions and political systems. Therefore, an understanding of farmland abandonment and its determinants in those physiographic regions is needed for sustainable development. This study aimed to fulfill this knowledge gap by evaluating the status of farmland abandonment and its determinants in different physiographic regions of the GRB. The local perceptions of farmland abandonment were also examined. The land that was previously used for agricultural activities but currently left idle and not converted to forest and urban land was considered as abandoned farmland in this study. Farmland was categorized as khet (under irrigation system) or bari (unirrigated) land in this study.

2. Materials and Methods

2.1. Study Area

The transboundary GRB is located in the central Himalaya region. It is situated between 25°37′32″ and 29°19′37″ North latitude and between 82°52′45″ and 85°48′18″ East longitude with an area of 40,378 km^2 (Figure 1). Due to its heterogeneous topography, the land use and land cover in the GRB varies. Forest (36%) and agricultural land (36%) are considered as the largest land cover types in the GRB. Barren land, snow/glacier cover, grassland, and water bodies account for 13%, 6%, 3% and 2% of land cover, respectively [28]. The agricultural land is predominantly found in the middle and southern parts of the GRB, whereas the northern part has limited agricultural land. Due to extreme variations in altitude (from 33 m to 8164 m) and climate, agricultural practices vary by physiographic region.

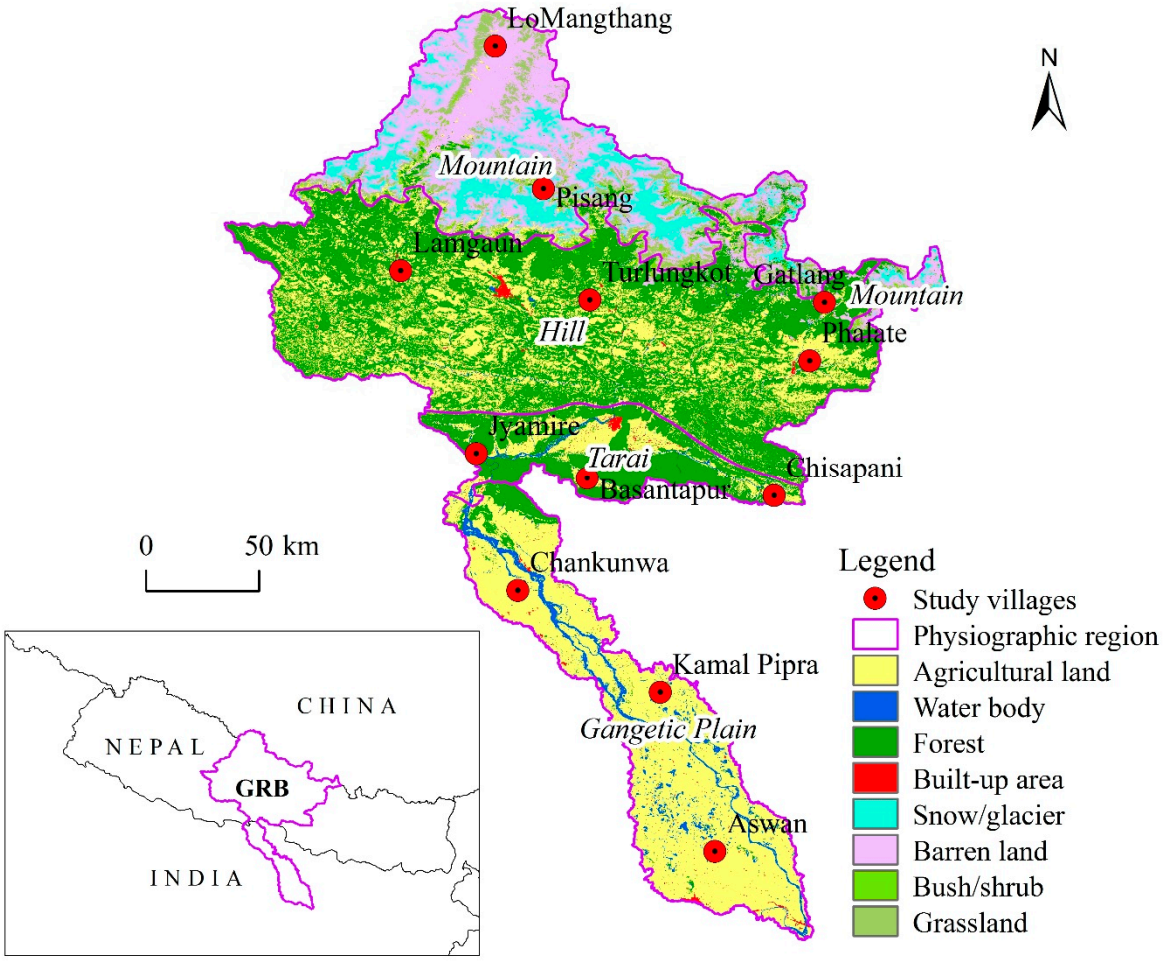

Figure 1. Location of the Gandaki River Basin (GRB) and selected villages in the different physiographic regions. Land cover data source: [28].

Based on the physiographic map of Nepal and India [29], this study was divided into four regions: Mountain (included high mountain, high Himalaya), Hill, Tarai (included Siwalik and inner Tarai) and Gangetic Plain (also called the Indo-Gangetic plain). The Gangetic Plain (GP) region lies in Bihar Pradesh (state) and Uttar Pradesh, whereas the Mountain, Hill, and Tarai regions lie in Nepal. The transboundary GRB also includes Tibet of China (accounting for nearly 8% of the GRB). This study only covered the parts of the GRB in Nepal and India (Figure 1).

2.2. Data Sources

Household Surveys, Key Informant Interview, and Focus Group Discussion

A semi-structured household survey was conducted to collect information on household characteristics, including location, availability of household assets, and abandonment of farmland. This study adopted multi-stage sampling methods. Firstly, all physiographic regions in the GRB were considered and each region was taken as a separate unit for further sampling. Secondly, 2–4 villages were selected purposively in each physiographic region. The criterion for the selection of village for household survey was a relatively large size of cultivated land in the village. The size of cultivated land was estimated based on the land use and the land cover map of the GRB and Google Earth images. A minimum threshold for sample size determination was considered and quota ranging from 40 to 56 was fixed, depending on the total number of households in the village. The households for the interview were selected randomly. The questionnaire was pre-tested and finalized before conducting the household survey in the study villages. The household survey was carried out between May and June 2018 in Nepal and in March 2019 in India.

A total of 639 households were surveyed from 12 villages in the four different physiographic regions: two villages in the Mountain; four villages in the Hill, three villages in the Tarai, and three villages in the GP (Figure 1 and Table 1). The heads of the household were interviewed. The sampled households represented 15% to 28% of the total household in the selected villages from the different physiographic regions.

Table 1. Number of households interviewed in each village.

SN	Village Name/District	Physiographic Regions	Total No. of Household	No. of Surveyed Household	Country
1	Pisang, Manang	Mountain	200	40	Nepal
2	Lomangthang, Mustang	-	240	53	-
3	Phalate, Nuwakot	Hill	220	53	-
4	Lamgaun, Baglung	-	200	55	-
5	Turlungkot, Lamjung	-	250	54	-
6	Gatlang, Rasuwa	-	260	55	-
7	Jyamire, Nawalpur	Tarai	325	54	-
8	Basantapur, Chitwan	-	280	55	-
9	Chisapani, Makwanpur	-	300	55	-
10	Kamal Pipra, Purba Champaran	Gangetic Plain	350	54	India
11	Aswan, Saran	-	380	56	-
12	Chankunwa, Pashim Champaran	-	350	55	-
	Total			639	

Focus group discussions (FGDs) and key informant interviews (KIIs) were also carried out to obtain in-depth information on farmland abandonment and its causes. The key informants consisted mostly of headmasters at local schools, local leaders, social workers, experienced farmers and chairmen (e.g., of rural municipalities, wards, women groups, mother groups, youth clubs and community forest user groups). A total of 72 KIIs were carried out in the 12 villages, with at least one FGD in each village; the participants were mostly intellectuals, local leaders, and farmers. A total of 8 to 25 participants were involved in each FGD. The FGDs were conducted during the morning time in public buildings, such as schools, ward offices, and municipality offices. A checklist was prepared for questions and answers during the FGDs and KIIs. In addition to primary data, secondary information (e.g., relevant unpublished documents and maps) were also collected.

2.3. Selection of Variables and Regression Analysis

The drivers of farmland abandonment differ based on the biophysical and socio-economic conditions. Previous studies analyzed predictors of farmland abandonment based on the contributions of different driving factors. The current study adopted some of these previously used variables

(independent/predictors) along with some new variables for analysis based on the bio-physical and socio-economic context of the study area (Table 2).

The dependent as well as many of the independent variables for regression analysis were dichotomous (e.g., yes or no). Only a few variables contained continuous data. Therefore, binary logistic regression (BLR) was used to examine the association between independent and dependent variables. BLR was adopted to assess the relationship between response and predictor as well as significant driving factors of farmland abandonment in this study. BLR is commonly used when there is one dependent variable [30,31]. The previous studies included the assessment of driving factors of cropland changes in the central Himalayan region of Nepal [32], farmers' livelihoods in Kathmandu Valley, Nepal [33], driving factors of farmland abandonment in southern Chile [34] and western Ukraine [35]. The binary logistic regression was described as follows (Equation (1)):

$$Y = log\left(\frac{P}{P-1}\right) = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \ldots\ldots b_nX_n. \quad (1)$$

Table 2. Selected variables, their definitions and probable relationships to farmland abandonment.

Variables	Definition	Expected Relationship to Farmland Abandonment
Response		
Farmland abandonment	Whether the household has farmland abandoned (if left farmland abandoned = 1, no farmland abandoned = 0)	
Predictors		
A. Locational characteristics		
Market centers	Distance from nearest market centers to residence (km)	If the market center is nearby, people can easily import food grains from the market and are not forced to cultivate their own land to maintain food security [8,9,34].
B. Land characteristics		
Distance to khet	Travel distance to khet land from residence (minutes)	Khet lands located at large distance from residence are more likely to be abandoned since they require more inputs (primarily labor force) to cultivate or protect crops from wildlife damages [9,23].
Distance to bari	Travel distance to bari land from residence (minutes)	Bari land located at large distance from residence is more likely to be abandoned since it required more inputs (primarily labor) to cultivate or protect crops [9,23].
Availability of irrigation facility	Lack of irrigation access (yes = 1, access = 0)	Khet lands having lack of irrigation facilities are more chances to be abandoned [9,23].
C. Household characteristics		
Family size	Family size (number of people in a household)	Small size households are more likely to abandon farmland since they do not have sufficient labor to farm the land in the absence of modern technology [9,10,23,26,35,36].
Reduction in labor force	Decrease population due to out-migration, death, marriage (out) within the past 10 years (decrease = 1, no decrease = 0)	A reduction in the agriculture labor force is likely to lead to farmland abandonment [8,10,20,35].
Household head gender	Gender of household head (Female=1, male = 0)	Female household heads are thought to be more likely to farmland abandonment compared to the male household head.

Table 2. *Cont.*

Variables	Definition	Expected Relationship to Farmland Abandonment
Household head occupation	Household head occupation (Other activities = 1, agriculture = 0)	Household head with other activities (non-agricultural) have more chances to leave farmland abandonment.
Household head agricultural training	Lack of training on agriculture practices (lack of training = 1, get training = 0)	Households having lack of training on agricultural machinery, technology, veterinary practices, modern farming are more likely to farmland abandonment [33]
Household head age	Age of household head (year)	Older household heads age more likely to farmland abandonment [23]
D. Physical assets		
Total khet land	Total khet area in ropani (1 ropani = 5476 square feet)	Households having large size of khet land more likely to farmland abandonment [9,23,36]
Total bari land	Total bari area in ropani	Households having large size of bari land are more likely to farmland abandonment [9,23,36]
Total number of livestock	Number of livestock (cattle, pig, buffalo, sheep, goat, horse, yak, and ox)	Households with large number of livestock are less likely to farmland abandonment since they have sufficient manure to replenish soil nutrients [23]
E. Income characteristics		
Off-farm income	Total off-farm income including remittance, salary, old-age subsidies, pension, and business income (000 USD)	Households with significant off-farm income are more likely to leave their farmland abandonment [8,9,20,23,24]

In this expression, Y is the dependent variables in which P denotes the probability of farmland abandonment (yes, no) and X_1, X_2, X_3, X_4, … X_n denote the independent variables and b_1, b_2, b_3, b_4, … b_n represented the regression coefficients.

To analyze the factors affecting farmland abandonment, BLR analysis was conducted using IBM SPSS statistical tools. In this model, 1 was assigned to households who had left farmland abandoned and 0 for households who had not abandon the farmland. The process of farmland abandonment was assumed to be a function of numerous variables, such as land characteristics, income sources, household size, physical assets, and household location (Table 2). Some of the variables, which were found important by the studies in the past, such as soil conditions, climatic information, socio-political, and labor markets, were not included in the regression model. Due to the time limit, we did not visit all the abandoned farmlands to obtain information on soil conditions. Regarding the labor market, this study focused only on foreign employment and remittances.

3. Results

3.1. Status of Farmland Abandonment

The number of households with abandoned farmland varied among the physiographic regions of the GRB. Nearly 51% of households had abandoned farmland in the Mountain region; the percentages in the Hill, Tarai and GP regions were 26%, 4% and 30%, respectively (Table 3). Overall, 25% of households abandoned their farmland in the GRB during the study period.

Nearly 48%, 15%, 4%, and 16% of total farmland (khet and bari) was abandoned in the Mountain, Hill, Tarai, and GP regions, respectively (Table 4). For khet land, 47%, 14%, 5%, 16% were abandoned in the Mountain, Hill Tarai, and GP regions, respectively; the corresponding percentages of abandoned bari land were 48%, 15%, 2%, and 0%, respectively. The proportion of farmland abandonment in the

total farm area was 16% in the GRB. In the Tarai and GP regions, the proportion of abandoned khet land was higher than the proportion of abandoned bari land, whereas the opposite trend was found in the Hills and Mountain regions.

Table 3. Number and percentage of households (HH) with abandoned farmland.

Response	Mountain		Hill		Tarai		Gangetic Plain		Total	
	No. of HH	%	No. of HH	%	No. of HH	%	No. of HH	%	No. of HH	%
Yes	47	50.5	57	26.3	6	3.7	50	30.3	160	25.0
No	46	49.5	160	73.7	158	96.3	114	69.7	479	75.0
Total	93	100	217	100	164	100	165	100	639	100

Table 4. Area and % of abandoned land by land type (areas in ropani).

Type of Land.	Mountain	Hill	Tarai	Gangetic Plain	Total
Total area of khet land	252.0	685.0	1045.3	3050.7	5033.1
Total area of bari land	301.0	1088.7	359.2	0.0	1748.9
Total area of farmland	553.0	1773.7	1404.5	3050.7	6781.9
Area of khet land abandoned	119.5	94.5	53.3	475.2	742.4
Area of bari land abandoned	145.5	162.5	8.7	0.0	316.7
Total area of farmland abandoned	265.0	257.0	61.9	475.2	1059.1
% of khet land abandoned	47.4	13.8	5.1	15.6	14.8
% of bari land abandoned	48.3	14.9	2.4	0.0	18.1
% of total farmland abandoned	47.9	14.5	4.4	15.6	15.6

3.1.1. Trends in Farmland Abandonment

Farmland abandonment activities have been reported since 1958 in the GP region of the GRB. According to the local farmers, farmland abandonment has been increasing rapidly in recent years. Figure 2 shows the cumulative area of abandoned farmland since 1993. The trend lines indicate annual increases in the area of farmland abandonment of 37 ropani (1 ropani = 5476 square feet) in the GRB, 13 ropani in the GP region of India, 2 ropani in the Tarai region, Nepal, 10 ropani in the Hill region of the GRB, and 12 ropani in the Mountain region of the GRB since 1993 (Figure 2).

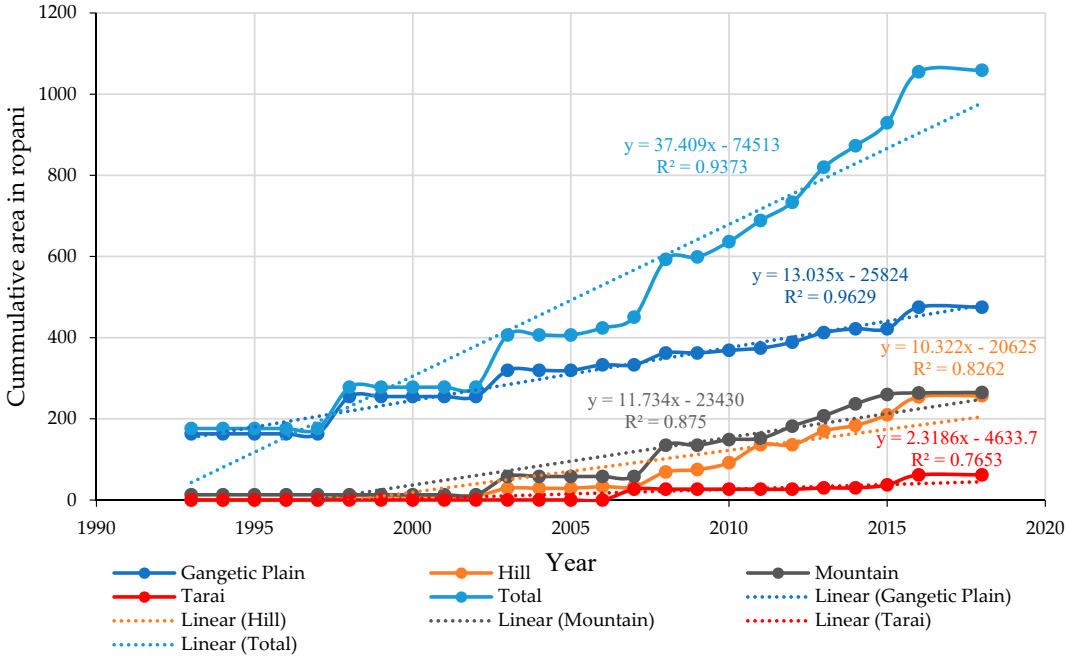

Figure 2. Trend of farmland abandonment in the GRB.

3.1.2. Condition of Farmland and Its Future Use

Currently, most abandoned farmlands have been converted to open lands with small grasses, bushes, small trees and sandy areas. A large proportion of abandoned khet land is covered with weeds and bushes in all regions (Table 5). All abandoned farmland in the GP region is khet land where paddy crops were grown before the abandonment. Nearly 74% of all abandoned bari land is covered with bush in the Hill, Mountain, and Tarai regions (Table 6).

The household heads were asked about the future utilization of their abandoned farmland. Among those surveyed, a minority of farmers reported their intention to reuse their abandoned farmland in the future. In the Mountain region, only 17 households indicated that they would reuse their abandoned khet land in the future, while 45 households indicated that they may not reuse the land; the corresponding households that may or may not use bari land in the Mountain region were 11 and 28 households, respectively (Figure 3). In the Tarai region, both khet and bari lands were more likely to be reused in the future. In the GP region, only 20 households intended to cultivate their abandoned farmland in the future.

Table 5. Present condition of abandoned khet land in the GRB (area in ropani).

Khet Condition	Mountain		Hill		Tarai		GP		Total	
	Area	%	Area	%	Area	%	Area	%	Area	%
Weed	29.5	24.6	1	1.1	4.7	8.8	74.6	15.7	109.8	14.7
Bush	50	41.8	75.5	79.9	28.6	53.6	64	13.5	218.1	29.3
Wood	0	0	6	6.3	0	0	4.7	1.0	10.7	1.4
Weed and bush	0	0	0	0	0	0	199.4	42.0	199.4	26.8
Bush and wood	3	2.5	6	6.3	0	0	0	0	9	1.2
Wood and others	25	20.9	0	0	0	0	0	0	25	3.3
Others	12	10.0	6	3.2	20	37.5	132.5	27.8	170.5	22.9
Total	119.5	100	94.5	100	53.3	100	475.2	100	742.5	100

Table 6. Present condition of abandoned bari land in the GRB (area in ropani).

Bari Condition	Mountain		Hill		Tarai		GP		Total	
	Area	%	Area	%	Area	%	Area	%	Area	%
Weed	0	0	14	8.61	0	0	0	0	14	4.4
Bush	106.5	73.20	120.5	74.15	5.3	61.63	0	0	232.4	73.3
Woodland	2	1.375	3	1.84	0	0	0	0	5	1.5
Weed and bush	0	0	6	3.69	0	0	0	0	6	1.8
Bush and weedland	21	14.43	12	7.38	0	0	0	0	33	10.4
Wood and other	0	0	2	1.23	0	0	0	0	2	0.6
Other	16	11.00	5	3.07	3.3	38.37	0	0	24.3	7.6
Total	145.5	100	162.5	100	8.6	100	0	0	316.7	100

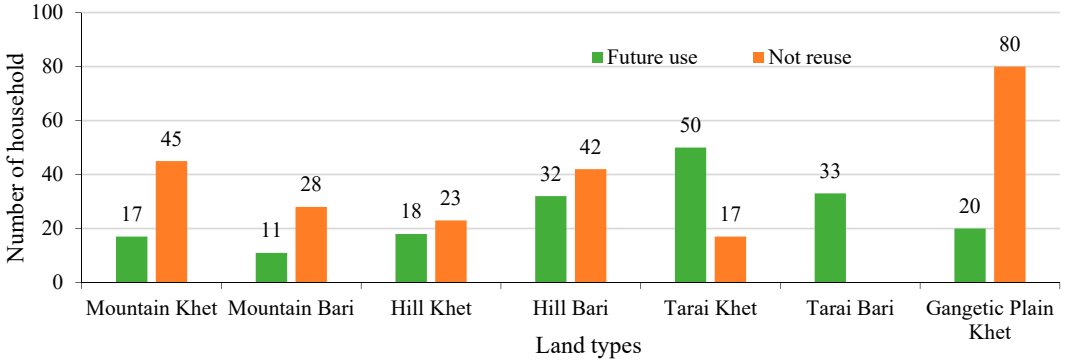

Figure 3. Future utilization of abandoned farmland.

3.2. Determinants of Farmland Abandonment

Different factors are attributed to farmland abandonment in the different physiographic regions of the GRB. The major variables affecting farmland abandonment in the GRB were distance between farmland, residence and markets, land characteristics, household characteristics, physical assets, and off-farm income source. BLR analysis was computed independently for the different physiographic regions and the results are compiled in Table 8. The constant values obtained by the models at the 95% significance level were 0.196 (R square = 0.468, RCP = 80.9, Chi-square 7.044) for the Mountain region, 0.924 (R square = 0.641, RCP = 87.1, Chi-square = 8.055) for the Hill region, 0.998 (R square = 0.550, RCP = 98.2, Chi-square = 4.577) for the Tarai region and 0.069 (R square = 0.422, RCP = 73.3, Chi-square = 8.123) for the GP region (Table 7).

Table 7. Summary of the model.

Summary	Physiographic Region			
	Mountain	**Hill**	**Tarai**	**Gangetic Plain**
Total N	93	217	164	165
Constant	0.196	0.924	0.998	0.069
PCP	80.9	87.1	98.2	73.3
R square	0.468	0.641	0.550	0.422
Chi-square	7.044	8.055	4.577	8.123

Abbreviation: N = total sample size; PCP = percentage correctly predicted.

The BLR analysis suggests that farmland abandonment was significantly explained by the distance between residence and market centers (p = 0.018), reduction in the labor force due to migration of economically active family members (p = 0.000), and household head age (p = 0.022) in the Mountain region. In the Hill region, eight factors were highly significant: distance from residence to market centers (p = 0.000), distance from residence to khet land (p = 0.001), distance from residence to bari land (p = 0.017), lack of irrigation facilities (p = 0.004), reduction in active labor force (p = 0.000), household head occupation (p = 0.028), household head training (p = 0.002), and total bari land (p = 0.007). In the Tarai region, the major driving factors were household head occupation (p = 0.015) and household head age (p = 0.012). In the GP region, the key determinants were distance from residence to market centers (p = 0.006) and lack of irrigation facilities (p = 0.003) (Table 8). The aforementioned variables had highly significant effects on farmland abandonment in the GRB. Other factors were marginally important but they were not statistically significant (Table 8).

Table 8. Details of the variables of the logistic regression models.

Explanatory Variable	Significance (*p*)			
A. Locational analysis	Mountain	Hill	Tarai	Gangetic Plain
Market centers distance (km)	0.018 **	0.000 **	0.770	0.006 **
B. Land characteristics				
Distance to khet (minutes)	0.756	0.001 **	0.345	0.869
Distance to bari (minutes)	0.381	0.017 **	0.681	x
Lack of irrigation facility (yes, no)	x	0.004 **	0.161	0.003 **
C. Household characteristics				
Family size (number)	0.362	0.162	0.989	0.252
Reduction in labor force	0.000 **	0.000 **	0.999	0.162
Household head gender (male, female)	0.507	0.142	0.998	0.420
Household head occupation	0.147	0.028 **	0.015 **	0.211
Household head training	0.428	0.002 **	0.301	0.678
Household head age	0.022 **	0.915	0.012 **	0.552

Table 8. *Cont.*

Explanatory Variable	Significance (*p*)			
D. Physical assets				
Total khet (ropani)	0.362	0.379	0.456	0.521
Total bari (ropani)	0.346	0.007 **	0.066	x
Total livestock (number)	0.121	0.163	0.605	0.785
E. Income sources				
Off-farm income	0.417	0.137	0.304	0.114

Abbreviation: ** indicates a significance level at 95%; x indicates a variable that was not included in the model.

3.3. Local Perceptions on Farmland Abandonment

This study also examined local perceptions about the factors driving farmland abandonment. Based on their experiences, the surveyed farmers indicated that decreasing labor availability of agriculture (57% of respondents), shifts in occupation from agricultural to non-agricultural (e.g., trekking, tourism and business) occupations (51%), decreased crop production (51%), and unpredictable weather events due to climate change (49%) were the main causes of farmland abandonment in the Mountain region.

Similarly, in the Hill and GP regions, the impact of climate change (e.g., decreased water resources, long periods of drought during the farming season, rainfall variability, and floods) was reported to be the key factor in farmland abandonment. Nearly 91% of respondents in the Hill region and 96% in the GP region reported that the effects of climate change were important factors in farmland abandonment. Respondent also indicated that increasing input costs for agricultural activities resulting from labor shortages contributed to farmland abandonment in the Hill and GP regions of GRB. Less farmland abandonment was observed in the Tarai region compared to the other regions. Marginal land, along the riverside and close to the forest side, were abandoned in the Tarai region. A total of 50% of farmers had abandoned farmland due to decreased production in the Tarai region (Table 9).

Table 9. Local perception of farmland abandonment in the GRB.

Major Causes	Farmers' Response and %							
	Mountain	%	Hill	%	Tarai	%	GP	%
Increasing cost of agricultural inputs	22	46.8	54	94.7	1	16.6	16	32.0
Shift occupations (agriculture to off-farm activities)	24	51.1	55	96.5	1	16.6	3	6.0
Decreased production	24	51.1	53	92.9	3	50.0	28	56.0
Decreased in the availability of agricultural labor force	27	57.5	30	52.6	2	33.3	12	24.0
Climate change (drought, flood, decrease water resources, and decreased in rainfall)	23	48.9	52	91.2	2	33.3	48	96.0
Far from home (long distance)	16	34.0	20	35.1	–	–	1	2.0
Out-migration	18	38.3	48	57.9	–	–	11	22.0
Lack of new agricultural technology	3	6.4	38	84.2	–	–	8	16.0
Crop damage by wild animals	1	2.1	14	24.6	–	–	1	2.0
Increased off-farm income	3	6.4	14	24.6	1	16.6	5	10.0

4. Discussion

4.1. Farmland Abandonment in Different Physiographic Regions

The physiographic regions of Nepal and India differ in terms of topography, the availability of agricultural land, productivity, environment, and overall development [29,37]. Therefore, the proportion of farmland abandonment varied among the physiographic regions of the GRB.

Mountain region: Both the percentage of household abandoning farmland and the proportion of area under abandonment were comparatively higher in the Mountain region. Farmland abandonment in the mountainous regions is expected to increase in the future [24,38]. One study found that a total of 28% farmland was abandoned from 2000 to 2010 in China's mountainous areas, where farmlands

were freely abandoned by farmer for the Grain for Green project (1999) to convert farmland to forest or grassland to mitigate soil erosion in the sloping Mountain region of China [19]. China and Nepal have a similar Mountain region topography in the China-Nepal border region, although the percentages of farmland abandonment rates are different due to policy and decision of household level. Farmland abandonment has also increased in the European mountain region in recent years. Based on remote sensing observations, 7.6 million hectares of farmland were permanently abandoned, particularly in Eastern Europe, Southern Scandinavia and Europe's mountainous regions from 2001 to 2012 [39]. The farmland abandonment in the Spanish Mountain regions since the 1950s resulted in decreased productivity with changing landscape, with woodland areas increasing from 10% to 37% and scrubland increased 42% to 60% during 1956–2001 [40]. From previous studies, it is clear that farmland abandonment is one of the pathways of land use change in Mountain regions everywhere in the world. The current study also shows a similar trend to other Mountain regions, but the process of farmland abandonment and spatio-temporal extent are different due to differences in the change in demography as well as major sources of livelihood at the household level and government policy.

Hill region: Farmland abandonment was also found to be high in the Hill region of the GRB. Historically, farmland abandonment has occurred more frequently in the Hill region of Nepal than in the Tarai region. One previous study revealed that the abandoned farmland was 44%, 23% and 33% in the upper-Hill, lower mid-Hill and lower plains regions, respectively, of the country in 2012 [20], whereas GRB Hill revealed 15%, which is almost half of what was reported previously. This lower proportion found in this study might be due to the selection of the study area and differences in methodology. Paudel et al. (2014) categorized upper and lower mid-Hill and used an actor-oriented approach, which was not statistically tested. A parcel-level analysis showed that approximately 49% and 37% of khet and bari land were abandoned, respectively, in the Sikles and Parche villages of the GRB [26]. Due to variation in the selection of villages, study time, and methods, the results varied within the Hill region. Khanal and Watanabe (2006) conducted household survey in 78 households from two villages during 1999–2000. After 2000, Nepal witnessed many changes, particularly in population growth, increased foreign migration, political changes and others [8,41,42]. Thus, it is clear that farmland abandonment is common in the Hill region and has been an increasing trend in recent years. The percentage of abandoned farmland is comparatively high in the Hilly and Mountainous regions. Our study also showed similar trend as observed in previous studies.

Tarai region: The Tarai region has the lowest level of farmland abandonment of all the regions in the study area. This is mainly due to its fertile agricultural land with access to an irrigation facility. Farmland abandonment has been found to be lowest in plains regions in other countries as well. For example, in Argeşş County in central Romania, the plains region had 10% farmland abandonment during 1990–1995 [43]. Müller et al. (2009) also studied Mountain, Hill and Plain zones (flat land) in their study and found comparatively lower abandonment in the plains among the zones. The low level of farmland abandonment in the Tarai region of GRB can be attributed to overall high land fertility, access to irrigation, and high land value. Nevertheless, studies on farmland abandonment processes in the Tarai region of Nepal are generally lacking.

GP region: The GP region had the second-highest level of farmland abandonment. The trend of farmland abandonment has a long history in the GP region. According to FGD and KII, there is an increasing trend of farmland abandonment. The Tarai and GP regions have almost the same topography, although farmland abandonment is higher in the GP region than in the Tarai region. The Tarai (Nepal) and GP (India) regions have similar bio-physical context, but frequent occurrence of drought and flood on the one hand and the difference in the socio-economic context, as well as the policies, legislation and governance systems on the other, could be the reasons for the differing rate of farmland abandonment.

4.2. Factors Influencing Farmland Abandonment

Mountain region: Different variables have played significant roles in farmland abandonment across the GRB. In the Mountain region, distance to market, decreasing population and age of household head were the predominant factors contributing to farmland abandonment. One of the major reasons for decreasing population is out-migration. According to the KIIs and FGDs conducted in the Mountain region, out-migration has greatly increased since the 2000s, with most migrants going abroad for labor employment. The change in population (i.e., decreased labor force) was found to be a significant cause and had a positive relationship with farmland abandonment in the Mountain region. According to the national census of Nepal, the population is decreasing in the Mountain region. The population of the Mountain region accounted for 9.9% of Nepal's total population in 1971; this percentage decreased to 8.7%, 7.8%, 7.3% and 6.7% in 1981, 1991, 2001 and 2011, respectively [44]. One study has found that abroad labor permits were officially recorded at 3605 in 1993–1994 and increased to 453,543 in 2012–2013; among them, 4.3% from Mountain, 45.1% from Hill and 50.6% from Tarai region of Nepal [45]. In addition, international migration such as rural mountainous areas to semi-urban and urban areas are very common in Nepal, resulting in a decline in farmland area and an increase in shrubland/grassland [46]. Based on the Nepal census report of 2001, the net number of migrants was recorded to be 255,000 immigrants from Mountain, and 831,000 from the Hill region [45]. The country's absent population was recorded at 762,181 in 2001, which increased by more than two-and-a-half-fold (1,921,494 population) in 2011 [44,47]. From the various historical records, the migration (rural-urban and abroad) trend has been very high in Nepal. The present study also reported the same results as previous national and regional level studies that population change (out-migration) is the major cause of farmland abandonment in the Mountain region of the GRB. One recent study also supported that migration and remittances were a significant cause of farmland abandonment in the Mountain region of Nepal [23]. This study shows that the extension of road network and access to market centers and easily available food encourage farmland abandonment in the Mountain region. According to the household survey, remittance is used primarily to buy food to support their household.

Hill region: The long distance to farmland from residence is an important factor contributing to farmland abandonment in the Hill region of the GRB. In the Hill region, farmlands located far from residence require high labor and other inputs and are less desirable to farmers compared to the closer farmlands near residences. Paudel et al. (2014) have also reported that distance from residence to farmland was an important factor of farmland abandonment. Farmlands are also being abandoned in areas located far from farmers' residences in rural areas of China [24,48] as well as India [22]. Farmers estimate tentative production and input cost and make decisions about whether to continue or abandon far-off farmlands. Similarly, the availability of irrigation plays an important role in farmland abandonment. In the Hill region of Nepal, a total of 40% of agricultural land lacks irrigation facilities and the agriculture production on these lands depends solely on monsoon rain [49]. Among the irrigated areas of Nepal, around 70% of the irrigation systems are managed by 'Farmer Managed Irrigation Systems', however, with environmental degradation, declining water resources, and high competition in the allocation of water resources, irrigation systems face major challenges [50]. In addition, irrigation problems are compounded by the presence of steep slope and frequent occurrences of floods and landslides in the Hill and Mountain regions in the country. In the absence of irrigation, the productivity of traditionally used crops decreases and there is less potential to increase cropping intensity. As a result, areas without irrigation facilities are often abandoned. Agroforestry programs on abandoned farmland could be an alternative so that natural hazards (floods, soil erosion, and landslides) could be reduced and at the same time, people could benefit financially. The land use policy, particularly increases in land tax on abandoned farmland could also be another measure to minimize farmland abandonment. Another important factor for farmland abandonment in the Hill region is the distance from residence to market which was also found to be significant for the Mountain region. The occupation of household head and training obtained by family members on agriculture development were also found to be important determinants for farmland abandonment.

The availability of natural capital, i.e., farm size, is another important determinant for farmland abandonment. As the farm size increases, the chances for farmland abandonment increases.

Tarai region: Household head with off-farm occupations was the key cause of farmland abandonment in the Tarai region. Urbanization in the Tarai region is rapid due to inter-regional migration for employment opportunities and better a life [51]. Since the late 1950s, migration to lower elevations (Tarai region) has mainly been caused by the higher agricultural productivity and the better quality of life afforded by the Tarai region [52]. Still, the Tarai region is gaining population from the Hill and Mountain regions, as Tarai provides more economic options to migrants. Population increase is mainly due to in-migration, more fertile soil, and advanced agriculture opportunities in the Tarai region [8,37]. One study presented that population changes caused by political events, such as the democratic movement in 1951 and the more recent Maoist revolution of 2005/2006, have caused significant population movements throughout the country, particularly in the Tarai region [44]. The opportunities for changing occupation from agricultural to off-farm (non-agriculture), such as business and other service-oriented jobs, are creating farmland abandonment in the Tarai region.

GP region: The GP region is dominated by farmland. However, due to the lack of irrigation facilities and market centers, the proportion of abandoned farmland is higher and it is increasing. Farming practices are directly affected by the lack of irrigation facilities in Bihar [53,54]. Farmers are faced with irregular monsoon rains, which regularly result in flooding, crop damage, and waterlogging problems in Bihar [54]. The Bihar government has introduced several subsidies and relief programs to minimize the effects of drought on agriculture; however, due to uncertainties and high transaction costs, it is not very effective to stimulate farmers to bring the land under cultivation after it has been damaged by floods and drought [55,56]. Currently, out of the 55.54 hundred thousand hectares of irrigated farmland in Bihar, only 30.64 hundred thousand hectares have irrigation facilities [57]. Sri Lankan farmers are currently adopting short season crops to overcome some of the drought effects [58] and more farmers use groundwater irrigation for farming in drought-prone areas in Bangladesh [59]. Drip irrigation has also been found to be another better method in water scarce areas. One study revealed that due to resources saving and cost-effectiveness, farmers have started a drip irrigation system in southern India [60]. Drip irrigation and crop diversification (drought tolerance crops, short-season crops) provide more effective ways to conserve water and can help minimize farmland abandonment in the GP region. In addition, groundwater could be an efficient method of irrigation in water scarce-areas. Nevertheless, the availability of foods/grains imported from elsewhere has supported the farmers who lacked adequate food supply. The availability of imported foods in the near-market showed a positive relationship to farmland abandonment in the GP region.

4.3. Farmers' Perceptions about the Reasons for Farmland Abandonment

Various perceptions of farmers regarding farmland abandonment were obtained from the different physiographic regions. The Mountain region has suffered a decreased agricultural labor force. According to FGDs, during the conservation and harvesting seasons, laborers have to be hired from other places with higher wages in the Hill and Mountain regions. During 1999–2014, abroad migration of youth resulted labor shortages in the village and consequently, more farmlands were left abandoned. Such processes of change have also been reported from the Andhi Khola watershed, which is also located in the Hill region of the GRB [8]. In addition, as the males migrate, the burden of agricultural work is also left to women and ultimately, the farmland is left abandoned [41].

Climate change effects have been recognized in all the regions of the GRB. In a previous study, 92% of respondents in the Chitwan-Annapurna region in Nepal reported experiencing climate change effects over the last 15 years, including unpredictable precipitation, drought, decreased water resources and changes in cropping patterns and phenology [61]. In the current study, approximately 49% and 91% of farmers reported that the negative effects of climate change had contributed to farmland abandonment in the Mountain and Hill regions, respectively. Previous studies have reported the

effect of climate change on farming practices manifested by increased temperature, decreased rainfall, decreased water resources, and drought [62–64].

Off-farm activities, mainly in the tourism industry, have been increasing in the Mountain region and are becoming a major source of income and an attractive way of life for people of the Mountain region in Nepal [65]. Based on tourism statistics, the total number of trekkers increased significantly from 2714 to 23,569 from 2005 to 2017 and the total number of tourist increased from 375,398 to 940,210 [66]. This increase in trekking and tourism has resulted in increased off-farm activities in the Mountain region and discouraged crop farming and consequently, an increase in farmland abandonment.

The effects of climate change, high agricultural input costs, out-migration and long distances between residences and farmlands were perceived as the major factors driving farmland abandonment in the Hill region. A study based on household surveys found that labor shortages resulting from out-migration had caused farmland abandonment in the hilly and mountainous regions of Nepal [67]. In recent years, increasing labor costs have also contributed to farmland abandonment in many rural areas in China [68].

In the Tarai region, around 50% farmers perceived the decrease in production as the main cause of farmland abandonment. It is obvious that according to the household surveys, FGDs and KIIs, only marginal land near to the forest, land at risk of flooding, and non-irrigated land were abandoned in this region. In the GP region, almost all farmers believe that the effect of climate change (i.e., drought, flood, decrease of water resources) encourages the farmland abandonment phenomenon. Bihar is also known as the multi-disaster prone state, mostly for recurrent floods, drought, and earthquakes [69]. Staple crops are already vulnerable due to drought and high costs of irrigation [56], therefore farmers have decreased interests in crop variability, particularly in drought-prone areas in Bihar [70]. Increases in dry periods and longer-growing periods have negatively affected crop production in Bihar [71]. Fluctuations in agricultural output have directly affected more than 36 million Bihari people in India [72]. Approximately 51% of people in the Bihar area are engaged in the agricultural sectors; however, the crop production in Bihar is lower than in other states of India [54]. Changing occupations are also creating labor shortages and contributing to farmland abandonment in the GP region. However, farmers are adopting alternative crops, such as banana and sugarcane, in areas previously used for paddy and wheat production in order to cope with the risk of climate change [73]. Such changes in cropping varieties are not commonly used in the study area. One of the policy provisions for reducing farmland abandonment could be emphasis on the introduction of crop varieties resistant to drought.

5. Conclusions

This study analyzed the status of farmland abandonment and its determinant in the GRB. Firstly, we concluded that the level and rate of farmland abandonment varied with the physiographic regions due to the biophysical and socio-economic conditions and accessibility differed highly among them. Around 51%, 30%, 26%, and 4% households abandoned farmland in the Mountain, GP, Hill and Tarai regions, respectively. Secondly, a number of variables play a significant role in determining the level and rate of farmland abandonment. However, their roles in determining farmland abandonment are not similar for all the physiographic regions, as indicated by the level of significance obtained from BLR. The locational variable, i.e., distance from residence to market centers was significant, except for in the Tarai region, whereas the distance from residence to farmland was only significant for Hill region. Similarly, the availability of irrigation facilities was found to be highly significant in the Hill and GP regions, but not in the Mountain and Tarai regions. The reduction in labor force was found to be highly significant in the Mountain and Hill regions, but it was not significant in the Tarai and GP regions. This is mainly due to the use of labor-substituting tools such as tractors, power tillers and threshers in the plain area. Socio-economic characteristics, such as occupation of household head, were found to be significant in the Hill and Tarai regions, whereas the age of the household head was found to be highly significant in the Mountain and Tarai regions. The farmers in the GRB perceived the effects of climate change, which had caused them to abandon their farmland, mainly in the GP region. Long-term

drought, flooding, and decreased water resources for agriculture were perceived as the main drivers of farmland abandonment by farmers in the GP region. Thirdly, the abandoned farmland was less likely to be reused as farmland in the future in all the regions except in the Tarai region, unless the policies and legislative provisions, particularly land ownership and taxation, and increases in productivity are made. Fourthly, there is the possibility of utilizing land resources left idle. Appropriate policies addressing the differences in physiographic region, as well as communities, need to be implemented. Agroforestry practices could be one of the alternatives in the Hill and Mountain regions. In the GP region, drought tolerant crops, rainwater harvesting, drip irrigation, and crop diversification could be more effective of minimizing farmland abandonment.

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